THE ADOLESCENT STRESS RESPONSE TO A NATURALISTIC DRIVING STRESSOR

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Dissertation prepared for the Degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF NORTH TEXAS

May 2000

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Wingo, Mary The adolescent stress response to a naturalistic driving stressor. Doctor of Philosophy (Biology), May, 2000, 58 pp., 12 tables, 3 illustrations, references, 59 titles.

The proposed study examined the role of anxiety and risk-taking in driving performance in adolescents. In addition to examining the sample as a whole, gender differences were assessed given earlier reports from our laboratory and others indicating that males and females differ with respect to risky behaviors to driving performance and anxiety. Adolescents' subjective and physiological responses to a driving simulator task were assessed. Anxiety was measured via self report and salivary cortisol. Participants provided a baseline saliva sample and 3 post-task samples for cortisol analysis. Subjective anxiety scores were obtained at both baseline and following the driving stressor. Information concerning impulsivity, as well as other psychological constructs was also collected at baseline. Unlike the pilot study, there were no relationships (with or without respect to gender) between salivary cortisol and both self-reported anxiety (state and trait) or impulsively measures for this sample. These results suggest that this group of adolescents may not have been anxious about the driving task. This discrepancy may stem from error introduced by the smaller sample size obtained from the initial findings or to other factors remaining outside the parameters of the current study. The task did, however, induce a slight hypothalamic pituitary adrenal (HPA) axis response indicating some physiological arousal. Males had significantly higher cortisol levels at baseline than females and at time point 3 while approaching significance at time points 2 and 4.

Females possessed significantly higher trait anxiety than males and all post task cortisol levels were positively correlated to age while time points 2 and 4 (with time point 3 approaching significance, p=0.09) were inversely correlated with Self Depreciation scores. Additionally, females had Persecutory Ideas scores that were also negatively correlated with cortisol at time points 3 and 4. For both the entire sample and males only, the correlation between post-task cortisol and driving performance was positive and approached significance (p=0.07 and p=0.08, respectively), suggesting that some HPA activation may be facilitative for successful driving task performance. Correlations between driving performance and psychological constructs were explored and discussed with and without respect to gender.

ACKNOWLEDGMENTS

I am forever indebted to my husband Rodney, whom without all the years of support and love I would not be where I am today.

In addition, I would like to extend my gratitude to Dr. Kim Kelly, Dr. Gerard O'Donovan, as well as the many other professors who have extended a substantial amount of patience and kindness to me over the years.

Finally, I would like to thank my family, whose heritable and nurturing inputs have allowed me to inspire, be inspired, and see the truth.

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INTRODUCTION

A working definition of stress

Stress is difficult to conceptualize and thus an acceptable definition has eluded researchers for years. The Scott Foresman Advanced Dictionary defines stress as “great pressure or force” or “great effort.” However, these definitions do little to crystallize how this pressure or effort originates in the organism. Many events within the mammalian shell contribute to the maintenance of homeostasis and this “great pressure,” as described above, may disrupt this delicate balance.

Hans Selye, a physician who performed his most creative experiments on the biological stress reaction in the mid twentieth century, was well aware of the precarious nature of such a definition, especially with its implication for humans in modern society (Selye, 1976, xvi). His original suggestion was that stress was the “rate of wear and tear in the body.” However, Selye himself conceded that the experience of stress is not necessarily detrimental to the organism; therefore, he amended his proposition as the “nonspecific response of the body to any demand” (Selye, 1976, xvi). Although still mutable in definition, stress is *not exclusively* one or more of the following: nervous tension, discharge of hormones from the adrenal cortex and medulla, nor the effectors resulting from the above, damaging to the organism, the deviation from homeostasis, or finally, a negative event. This abstraction, which thus far has no precise definition, possesses however a very specific effector response. Although it manifests itself as a specific syndrome, Selye posits that stress is nonspecifically

induced. As a result of much physiological research, he postulated the concept of a general adaptation syndrome (GAS) to describe the pattern of events that take place within an organism as the interval from the initial reaction to a stressor proceeds.

G A S is characterized in part with an initial activation of the sympathetic nervous system. Subsequent sympathetic adrenal medullary (SAM) axis and hypothalamic pituitary adrenal (HPA) axis responses occur, resulting in a cascade of physiological consequences. As a result of the stressor exposure, three temporally dependant patterns emerge: the acute, resistive, and exhaustive phases. Initially, it must be noted that a number of messengers, both humoral and neural, are responsible for the initiation of the alarm reaction. One reliable response of the acute phase within the alarm reaction consists of the secretion of catecholamines into the blood stream from the humorally mediated "fight or flight" (SAM) response. The alarm phase consists of a rapid sympathetic neural mobilization while a second, prolonged, hormonal secretion follows suit: the SAM axis participates in the release of catecholamines while the HPA axis liberates glucocorticoids and mineralocorticoids. The interplay between these three systems results in a physiological nexus that interacts rather intimately with the rest of the organism. For example, the autonomic nervous system (ANS) includes and is responsible for the operation of the sympathetic nervous system (SNS), which in turn, stimulates the operation of the HPA axis.

Disturbance of the smooth regulation of the SAM axis occurs as a response to a number of stressors including fear, pain, and frustration (Selye,

1976). Depending on the stressor, physiological and psychological events are interpreted by the various cortical association centers as conscious disruptions (Mandler, 1984). These centers project afferent fibers into the paralimbic cortex and limbic centers. At this point in processing, a rich coordination occurs between central, peripheral, and somatic influence. The paraventricular nucleus in the hypothalamus sends messages to the pituitary gland via secretion of releasing hormones to the vascular body known as the median eminence, which in turn, stimulates the anterior pituitary via neuroendocrine release. The pituitary then releases additional hormones controlling many homeostatic processes in the body. Stimulation of the hypothalamic lateral nuclei activates and the solitary tract of the brain stem coordinates the general sympathetic response (Guyton and Hall, 1996). During this "fight or flight phase," the following physiological events take place as a result of an all-or-nothing mass discharge phenomenon of sympathetic neurons: increased arterial pressure, increased cellular metabolism, increased glycolysis in the muscle and liver, increased blood glucose, increased blood flow to the muscles that will be used in response to the challenge, increased strength, and increased mental acuity (Guyton and Hall, 1996). This powerful systemic response, however, is acute and must have an equally powerful, longer lasting humoral backup. One such humoral system comes into play: the release of epinephrine and norepinephrine from the adrenal medulla from initial sympathetic stimulation, or the SAM response. This process serves to sustain the sympathetic neural activity initiated via the hypothalamus and brain stem. These hormones are integral for the maintenance of sympathetic tone

because their effects last five to ten times as long neural stimulation (Guyton and Hall, 1996). With another commanding hormonal system, the HPA axis, the hypothalamus sends corticotropin releasing factors via neuroendocrine connections to the anterior pituitary. The pituitary, in turn, is stimulated to release adrenocorticotropic hormone (ACTH) into the blood stream. In this case, ACTH stimulates the zona fasciculata layer of the adrenal cortex to release, in humans, cortisol. Cortisol, in turn, is a steroid that permeates the lipid bilayer of the target cells and binds with steroid binding receptors. As a result, the DNA transcription rate (among other events) is modified throughout much of the organism. Depending on the type of cell affected, a variety of events can transpire. For instance, glucose, amino acid, and fat metabolism become drastically altered (Guyton and Hall, 1996). Additionally, glucocorticoids are extremely efficient at exerting a powerful influence over various hepatic functions to achieve these goals. Cortisol is responsible for stimulating a process known as gluconeogenesis in the liver. The effects of this mechanism are twofold: first, amino acids are mobilized from locations outside the liver and second, these amino acids are converted at an accelerated rate to glucose (Guyton and Hall, 1996). In addition, it is believed that cortisol and related hormones depress the oxidation of NADH to delay the entry of glucose into many types of cells and as a result, blood glucose levels escalate. With respect to protein metabolism, inhibition of extrahepatic peripheral amino acid uptake and widespread extrahepatic protein concentrations decrease. Fatty acids are liberated and oxidized from parent adipose cells to partially compensate for undernourished

peripheral cells. Inflammation is generally inhibited, but in the case of infection, tissue destruction is usually more extensive.

Additional consequences can be seen in rodents. Corticosterone is a closely related corticosteroid secreted in response to stressful stimuli in rats and serves physiological purposes that are identical to cortisol. Within a short period after exposure to stressful stimuli, rats demonstrate reduced thymus mass, increased adrenal mass, and bleeding peptic ulcers (Selye, 1976). It must be maintained, according to Selye, that the alarm reaction most likely entails a generalized "call to arms" of the organism's defense system. During this phase of adaptation, the organism must often go through a substantial degree of suffering and lack of resistance to the stressor at hand. Selye has suggested from experimental evidence that if the stimulus is so noxious so that continuous exposure is unsuitable for life, then death for the organism will follow within the "first hours or days" (Selye, 1976, pg. 37).

However, if the threat is prolonged, yet tolerable, a secondary mechanism is likely to come into play: resistance. This phase occurs as a response to physiological adaptation to the hypervigilant state that the organism experienced during the alarm stage. During this state, resistance to the offending agent increases markedly while other types of resistance drop markedly (Selye, 1976). Two examples, as discussed above, are the anti-inflammatory properties of cortisol and the lack of resistance to foreign agents. However, the continued mobilization of glucose, amino acids, fatty acids, as well as other substances for feeding the organism's existence during this lack of homeostasis has serious

consequences if the stressor does not abate. If this stage persists for too long, the exhaustion phase comes into play and the animal faces two alternatives: irreversible physical damage or death. As a philosophical overture, Selye describes stress as an “equalizer of activities.” He maintains that no part of the organism should be over-exerted for extended periods of time and that the experience of stress is an adaptive function to counteract this type of physiological imbalance (Selye, 1976).

Overview of clinical stress research

It is remarkable too that an organism’s cognitive interpretation can result in substantial biological changes. In recent years, much of the focus of stress research lies with the impact of the humoral and neural components of the stress response to the immune system (Morell, 1995). For instance, stressful life events are associated with a dose-response related increased risk of acute respiratory infections (Cohen et al., 1991) and symptomology (Stone et al., 1992). Furthermore, viral infection has been reported to be associated with a negative stressful appraisal of life events, a lack of perceived control, and negative mood (Cohen et al., 1991). On the other hand, stressful life events, both positive and negative, share a relationship with pronounced cold symptoms (Stone et al., 1992). In addition, decreases in the immune response to recombinant hepatitis B vaccine are observed in students with anxiety and limited social support after taking an academic examination (Glaser et al., 1992). Altered IgA, IgM, and IgG levels have been observed in students with high stress perception after a difficult academic exam (Maes et al., 1997). An extensive

meta-analysis determined a negative relationship between stress and proliferative responses to natural killer cells and mitogens. In addition, it was shown that stress exposure correlates negatively with circulating B cells, T cells, helper T cells and cytotoxic T-cells (Herbert and Cohen, 1993).

It has also been recently demonstrated that there are detrimental neuronal consequences of sustained glucocorticoid elevation. It has been reported that glucocorticoids contribute to neurological damage in humans (Sapolsky, 1996). The author suggests that a negative relationship exists between length of time depressed and hippocampal volume. In addition, a negative relationship exists between length of combat exposure and hippocampal volume (Sapolsky, 1996). Indeed, this evidence is additionally substantiated by a dose-related positive correlation between excess cortisol abnormally secreted in Cushing's Syndrome and hippocampal volume. Atrophy is thought to be caused by glucocorticoid occupation of hippocampal glucocorticoid receptors and the subsequent poor calcium and glutamate regulation in that area. This results in an initially reversible, and possibly later irreversible, atrophy to the hippocampal dendrites. Consequences for consciousness due to hippocampal malfunction in general may include impairments in decision making and in forming declarative long-term memories (Guyton and Hall, 1996).

A working definition of anxiety

One of the responses to stress is anxiety; this powerful psychological reaction is often initiated in part by the organism's limbic system in times of environmental uncertainty (Goldstein, 1995). If the HPA axis is activated during

times of anxiety, then the question remains at how to define anxiety in general. Goldstein, a structuralist, suggests that the experience of anxiety and a "catastrophic" reaction is the result of a profound lack of threat objectification (Goldstein, 1995). In other words, to evaluate or appraise an unfamiliar situation that presents itself and to act adaptively, the organism must separate itself perceptually from its environment and analyze the threat in a more objective manner. Indeed, this seemingly simple change of cognitive perspective may be involved in the attenuation of the stress reaction and thus serve to dampen HPA axis activation (Mandler, 1984). In addition, Lazarus posits that adaptive functioning involves an organism's response to many individual differences involving utilization of many different types of ego - defense mechanisms that distort reality (Lazarus, 1991). For example, individuals with greater ego - resiliency, or coping abilities, showed greater physiological and emotional flexibility after an academic exam, e.g., they were able to separate themselves from the stressor and thus had the ability to adapt to the stressor at hand. As a result, subjective stress was less and autonomic nervous system activity dropped (Spangler, 1997).

A working definition of risk-taking

Risk-taking enters the arena of cognitive control. Risk-taking behavior, or the willingness to make decisions based on ambiguous information, bears a negative relationship with anxiety levels (Schaninger, 1976; Agarwal, 1977). In a study of operators in the chemical industry not only does a high level of anxiety represent a loss of cognitive control, but it also produces a significant aversion to

making risky decisions by increasing the time needed for effective problem solving (Fabry and Dvorakova, 1992). Mount Everest climbers are athletes willing to weather extreme circumstances to reach a goal. These athletes have much higher levels of risk-taking and sensation seeking and lower levels of worry and anxiety than do other elite climbers (Brevik, 1996). On a less physical, more abstract level, credit users who have higher anxiety, lower self-efficacy, and a higher external locus of control are more likely to use credit unsuccessfully (Tokunaga, 1993).

Gender specific differences between effects of stress and HPA activation

It is important to note that the various physiological and psychological effects of stress and HPA activation differ qualitatively and quantitatively with respect to gender and age. A comprehensive meta-analysis based on gender personality traits suggested that males possess higher assertiveness and slightly higher self esteem scores than females. Females, on the other hand, score higher than males in traits such as anxiety and trust (Feingold, 1994). These gender differences remain constant across such variables as age, educational level, and national origin. Women with lower back pain tended to have slightly higher CSF cortisol, serum cortisol, somatization, and depression levels than men with lower back pain (Hyyppa et al., 1985). A dichotomy between the sexes exists regarding aggression, patience, and impulsively scores. Although men scored significantly higher than women on these variables, women scored higher on confrontational avoidance (Gladue, 1991).

Additional differences may be seen between newlywed couples during

conflict. If the dynamic that exists between the couple includes the wife complaining or criticizing and the husband responding by withdrawing, the wife, but not the husband is likely to experience a greater release of norepinephrine and cortisol (Kiecolt-Glaser et al., 1996). However, under experimentally induced speaking tasks, the norepinephrine responses were more elevated in men than women (Mills et al., 1995).

With adolescents, a longitudinal perspective on distress behavior and cortisol reactivity to an experimental stressor indicated that over a one year period, cortisol levels decreased for girls but not boys (Susman et al., 1997). In this same study, those adolescents who had high cortisol responses at the time of a phlebotomy stressor reported higher levels of depression and conduct disorder one year later. Nicotine also has a gender specific effect on salivary cortisol secretion in adolescents, as females who are heavy users were reported to have higher cortisol levels than equivalent male counterparts (Canals et al., 1987).

Methodical problems in stress research and the use of simulators

While many stressors used experimentally, e.g., mental arithmetic and academic examinations, are relatively well controlled events, neither are applicable to most individuals on an everyday basis (Manuck et al., 1985; Marucha et al., 1998). Additionally, it is possible that the physiological reaction exhibited may not completely represent the stress response seen in a more inherently naturalistic environment.

One plausible solution to this methodological conundrum is the use of

simulators. For instance, several interesting studies have been constructed using flight simulators. In one such study, increased plasma proopiomelanocortin (POMC) and cortisol secretions were observed during simulated combat military flight (Leino et al., 1998). The authors proposed that when the complexity and information load of the combat task exceed the pilots' cognitive limit, sympathetic discharge and release of pituitary hormones occurred. In a similar vein, Boeing 737 pilots also experienced an increase in plasma cortisol during a simulated flight stressor (Sive and Hattingh, 1991).

Driving as a naturalistic stressor in Western society

One very common stressor that occurs in Western civilization is driving. Support of use of a driving simulator as a stressor is evidenced by an increase in heart rate as driving demands are increased (Ashton et al., 1972). An interesting study of stress and fatigue in long distance bus drivers found that secretion rates for catecholamines and cortisol levels, as well as stress and anxiety scores, increased only during the beginning of a driving shift, indicating stress response induction when initiating a goal (Raggatt and Morrissey, 1997). In addition, stress may elicit a predisposition for an increased incidence for motor vehicle accidents (Matthews et al., 1998). These researchers found that an aversion to driving was a strong predictor of a stressed mood. Furthermore, a dislike for driving was correlated with reduced control skills in a driving simulation. A plausible explanation for this lack of control is the diversion of attention to irrelevant processing (Matthews et al., 1998).

For older adults, cortisol responses to a driving stressor are negatively

correlated with self esteem scores. Additionally, significant elevations in ACTH were observed in the simulated driving stressor alone. This study showed that HPA responses for older adults are not uniform and that successful aging may result partially from maintaining greater physiological hardiness when confronted by a stressor (Seeman et al., 1995). With respect to gender and simulated driving, older females show greater plasma cortisol responses than their male counterparts (Seeman et al., 1995). A recent survey revealed that males of all ages have a consistently higher risk of motor vehicle accidents per mile driven than females (Massie et al., 1997). In addition, variations in accident rates for both genders were observed with a U-shaped pattern emerging as a function of age with males having consistently higher rates.

Adolescent driving statistics

Although the studies cited above have utilized simulated driving and driving habits as more naturalistic stressors, none has focused on the stress response of a younger population. This group is intriguing, for it is adolescents who experience a high motor vehicle accident rate and auto fatalities. For example, although teenagers only accounted for 10% of the U.S. population, they are disproportionately responsible for 15% of motor vehicle deaths in 1997. Additionally, motor vehicle collisions accounted for 36% of all deaths for adolescents (Insurance Institute for Highway Safety, 1997).

In 1997, 66% of adolescent fatalities in motor vehicle collisions were male. Moreover, the death rate for male adolescent drivers in 1997 was 12 per 100,000, twice the rate as females (Insurance Institute for Highway Safety,

1997). As for alcohol involvement in automobile fatalities, 28% of males versus 13% of females have blood alcohol levels of greater than 0.10 %. A more systematic study conducted by Vavrik (1997) divided adolescent male drivers into low and high risk driving groups and had these participants complete 5 personality assessments from the Jackson Personality Inventory and 15 from the Personality Research Form. The low risk group consisted of drivers that had no at fault accidents in a two-year period while the high risk group consisted of drivers who had two or more at fault-accidents in the same time period. As expected, the high risk group had much higher risk-taking tendencies and lower harm-avoidance than the low risk group. Interestingly, the high risk group also had higher resources of self esteem, exhibitionism, dominance, and desirability. With bravado, however, comes a price, for the high risk group scored significantly lower on measures such as innovation, which is a reflection of "inventiveness and creativity," than the low risk group. A plausible explanation the author affords for this disparity between the groups may be that positive reinforcements for risky behavior are legitimized and reinforced by society (Rigby et al., 1989).

Gender specific differences between adolescent anxiety and risk-taking tendencies

As for a gender difference, delinquent behavior is correlated with being male, adolescent, and impulsive. Risky behavior for males is inversely related to responsibility (Krishna, 1981). Risk-taking has also been found to be significantly correlated with traits such as impulsivity and sensation seeking (Miller, and

Byrnes, 1997; Stanford et al., 1997). In addition, risk-taking traits were found to have gender specific differences only in certain contexts. The authors suggest that future research on risk taking needs to focus on situations that promote risk taking, such as culturally defined competitiveness, to understand gender specific differences.

As for anxiety, there exists a negative correlation between internalization of traffic norms and risk taking (Shoham et al., 1984). It has been shown by Butler and Mathews (1987) that trait anxiety shares a positive relationship with negative global self evaluation in response to negative events whereas state anxiety shares a similar kinship with self evaluation correlating with localized, fewer self-encompassing negative events, i.e., a single evaluation. Speilberger (1966) states that trait anxiety is a more permanent personality fixture, whereas state anxiety reflects a more transitory, situational mood. Additionally, it has been reported that the greater the internalization of self-encompassing negative events, the higher the anxiety exists for committing traffic transgressions (Shoham et al., 1984). Furthermore, while the driver's willingness to take risks is attenuated, the individual suffers from stress while driving and thus may be caught up in a positive feedback loop where he or she becomes so anxious that disorientation causes a transient loss of vehicular control. As for risky drivers, low anxiety is present, but impulsiveness scores are high; this is often expressed as blatant disregard for traffic norms. Because adolescents' underdeveloped driving risk perceptions are related to driving inexperience, they have a tendency to underestimate the threat of personal injury (Stinson-Kidd and Holton, 1993). It

was determined that not only do adolescent males have riskier driving practices than females, but that this type of risk taking behavior shares a health relationship with alcohol consumption. Based on Piaget's developmental theory, it was suggested that as the physiological transition from childhood to adulthood ensues, concrete thought processes are gradually abandoned for the formal-operational ones. If this cognitive development lags behind emotional development, false confidence or "braggadocio" might prevail before the actual cognitive skill develops. Moreover, a survey taken of male drivers of all ages yielded interesting conclusions (Finn and Bragg, 1986). Although both young and older drivers maintained that younger drivers were more likely to have an accident (as opposed to older drivers), the younger respondents perceived their *own* chance of accident involvement, as opposed to that of their peers, as much lower. This trend was not observed with the older male drivers.

The adolescent stress response

Finally, a pilot study was conducted (Wingo, et al.,1999) exploring the stress response of adolescents. The aim of this study was to examine the stress response associated with learning a new task, in this case, driving assessed via simulators. Additionally, the relationships between perceived anxiety and driving performance were examined. The participants (11 females, 11 males) were enrolled in a drivers' education course offered at UNT to receive training for drivers' licenses. The driving simulation exercises consisted of the participant sitting in a car-like unit and employing offensive and defensive maneuvers to a realistic driving scenario displayed on film, including exercises in signaling,

braking, steering, acceleration, and speeding. Four saliva samples were taken: one at baseline (one week prior), and three after the driving simulation task taken at 10 minute intervals. Results indicated that there was a significant correlation between self reported anxiety and cortisol immediately following the driving stressor ($p=0.02$) as well as 10 minutes post-task ($p=0.04$). Further analyses indicated that for females the relationship immediately post-task was significant ($p=0.03$) and approached significance ($p=0.08$) ten minutes post-task. All of the correlations for females were positive, indicating that higher self-reported anxiety was associated with increased cortisol responses. For males, although not significant, relationships at all time points were negative. Unexpectedly, cortisol levels had no effect on driving performance for either gender. While there are numerous possible explanations for the gender difference present between the correlations of state anxiety and cortisol levels, these findings may indicate that a gender specific stress response may be related to the willingness to take contextually defined risks. Support may be seen in work reported by Gladue (1991) who posits that females reported more likely to avoid confrontation and be less impulsive than males.

Males and females possess, as a whole, individualistic styles for confronting stressors presented by the evolving conditions of everyday life. Both styles have adaptive value and may utilize different coping strategies. Because adolescent males have a greater tendency for risky behavior, and thus have more automobile accidents, the unique stress response difference between the sexes must be examined more closely.

The proposed study examined the role of anxiety and risk-taking in driving performance. Anxiety was measured both subjectively and objectively, via self report and salivary cortisol, respectively. In addition to examining the sample as a whole, gender differences were assessed given earlier reports indicating that males exhibit riskier behaviors (Stinson-Kidd and Holton, 1993) as well as being less anxious than females (Wingo et al., 1999). Adolescents' subjective and physiological responses to a naturalistic stressor, a driving simulator task, were assessed. Participants provided a baseline saliva sample (time 1) and 3 post-task samples (times 2-4) for cortisol analysis. Additionally, subjective anxiety scores were obtained at both baseline (trait anxiety) and following the driver stressor (state anxiety). Information concerning risk taking, as well as other psychological constructs was also collected at baseline.

Research Objectives

Research Objective 1

Relationships between salivary cortisol and self reported anxiety (both trait and state), and impulsivity were determined. Correlations between salivary cortisol levels at time points 1 - 4 and state and trait anxiety measures were performed. Correlations between salivary cortisol levels at time points 1 - 4 and the Impulse Expression measure were conducted as well. It was predicted that there would be a negative correlation between Impulse Expression and salivary cortisol at time points 2 and 3 and a positive correlation between salivary cortisol and state and trait anxiety at time points 2 and 3.

Research Objective 2

Gender differences were expected such that adolescent males were hypothesized to have greater risk taking tendencies (as measured by impulsivity scores) than females. Data were analyzed via an independent samples t-test.

Research Objective 3

Correlations were explored between state anxiety scores and salivary cortisol levels at all time points with respect to gender. As reported previously (Wingo et al., 1999), females were proposed to share a positive relationship between anxiety state scores and salivary cortisol levels at time points 2 and 3 after the driving task. It was hypothesized that males possess a negative or no correlation between anxiety state scores and salivary cortisol after the driving task.

Exploratory Analysis

Relationships between the overall driving score and driving errors, and physiological and psychological measures were explored with and without respect to gender. Correlations, both Pearson and partial, were calculated between cortisol levels, age of participant, questionnaire scores (including the remaining BPI subscales: Hypochondriasis, Depression, Denial, Interpersonal Problems, Alienation, Persecutory Ideas, Thinking Disorder, Social Introversion, Self Depreciation), overall driving score and the type of error made while performing the driving task. These types of errors included, but were not limited to: braking, steering, speeding, and turning.

MATERIALS and METHODS

Participants

At the University of North Texas (UNT) in Denton, Texas, courses are offered in drivers' education to improve driving skills and grant drivers' licences. A nonprofit program, "Teen Learn to Drive," is a 48-hour course offering low-cost drivers' education to adolescents in Denton and the surrounding communities. Classes are held twice each long semester and twice each summer and consist of 32 hours of classes in traffic law and driving technique, four hours of driving, four hours of driving observation and 12 hours of driving simulation on a Doron Simulation System 11 (Doron Precision Systems, Inc.).

The first two weeks of class are spent in preparation for a learner's permit test, which covers primarily traffic laws and theoretical maneuvers, rather than driving skills. As a result, participants during this time did not have any simulator or "in car" driving experience. This critical period of time within the course provides an excellent opportunity for challenging inexperienced drivers with a novel stressor. Fifty-five adolescent male and female volunteers age 15-18 years (25 females, 30 males) were recruited via classroom announcements while enrolled and attending the drivers' education course. Through computer monitoring of each driving station, each student's driving performance was checked during the simulator film. Participants as well as their parents were informed about the nature of the study and were required to sign informed consent releases.

Materials

Driving simulator

The Doron Simulation System 11 consists of an actual driver's seat with various realistic components including a steering wheel, turn signals, ignition, odometer, headlight switch, gas and brake pedals, and parking brake. The system also consists of films that contain markers at various time points that measure driving errors monitored by the computer for scoring purposes. While some films test very basic driving skills such as signaling and turning, others include very complex maneuvers involving reaction time and tests of spatial skill. The 20 minute film used to test driving skills in the proposed study contains many challenging scenarios through which the student must maneuver. These scenarios include averting oncoming traffic and aggressive drivers as well as avoiding unyielding pedestrians.

Basic Personality Inventory (BPI)

The BPI (Jackson, 1996) is a 240 item, true or false questionnaire that assesses the following personality characteristics: Hypochondriasis, Depression, Denial, Interpersonal Problems, Alienation, Persecutory Ideas, Anxiety, Thinking Disorder, Impulse Expression, Social Introversion, Self Depreciation (Jackson, 1996). Of these, the Anxiety and Impulse Expression subscales were used to assess trait anxiety and risk taking propensities. A high Impulse Expression score suggests a tendency to "undertake risky and reckless actions" (Jackson, 1996, pg. 8). The BPI was used to assess trait anxiety instead of the trait inventory of the State-Trait Anxiety Inventory (STAI) to avoid the similarity of

question types between the trait and state portions of the STAI.

Additionally, the trait anxiety subscale of the BPI enjoys a higher correlation (0.70) with the state portion of the STAI than with the trait portion of the STAI (0.65) (Speilberger, 1983). The Anxiety and Impulse Expression portions of the BPI have been demonstrated to have moderate alpha reliability coefficients of 0.82 and 0.90, respectively. The corrected BPI scale validity for Anxiety and Impulse Expression is 0.61 and 0.42, respectively (Jackson, 1996).

State-Trait Anxiety Inventory (STAI)

The state inventory of the STAI was used to assess "state" anxiety (Speilberger, 1983). The STAI state inventory is a twenty-item self evaluation in which each question is rated with a 0-4 Likert-type scale and is designed to measure the current level of apprehension (state). The state portion of the STAI has been demonstrated to have high alpha reliability coefficients when completed after a stressor, ranging from 0.98 to 0.94 post-stressor for highschool students (Speilberger, 1983).

Saliva sampling

Because saliva has been shown to accurately reflect biologically active cortisol fractions in a noninvasive manner, saliva was collected for the purposes of measuring cortisol in this study (Aardal-Eriksson et al., 1998). Saliva samples were obtained using Salivettes[R.] Each numbered and coded Salivette consists of a plastic tube containing a gauze pad. Participants chewed on the gauze pad until it was fully saturated with saliva and then placed it back into the tube. Each participant provided four samples. The coded samples were frozen at -20C until

assay. With some modifications in existing protocol perfected by Dr. Clemens Kirschbaum at the University of Trier, in Trier, Germany, cortisol in saliva was measured by commercially available radioimmunoassay kits (Kirschbaum et al., 1989). The samples obtained from this study were sent to Dr. Kirschbaum's laboratory for analysis.

Procedure

A week before the driving challenge, participating individuals provided a baseline saliva sample and completed the BPI inventory. On the test day, the students participated in the driving simulator task and provided three post-task saliva samples at ten minute intervals via the methods previously described. In between the first and second post task measures, participants completed the state anxiety portion of the STAI.

Each student's performance, including type and number of errors, was electronically graded by the simulator system. Since this driving task is actually a graded part of the fee-based course for which obtaining a driver's licence is dependent, incentive to perform well was strongly present. As an added incentive, the participant in each group with the highest simulated driving score received a monetary prize of ten dollars in cash.

Data analysis

Data Analysis for Research Objective 1

Pearson product coefficients were computed between state anxiety scores, trait anxiety scores (Anxiety), Impulse Expression scores, and salivary cortisol levels at all four time points.

Data Analysis for Research Objective 2

Gender differences between the Impulse Expression scores were explored using an independent samples t-test.

Data Analysis for Research Objective 3

Correlational analyses were performed between state anxiety scores and salivary cortisol levels at time points 1 - 4 for males and females.

Exploratory Analysis

Descriptive statistics of all variables were calculated and explored. Exploratory correlational analyses with and without respect to gender were calculated between salivary cortisol levels, age, state anxiety scores, Anxiety (trait) scores, Impulse Expression inventory scores and the remaining variables, including ten subscales of the BPI (Hypochondriasis, Depression, Denial, Interpersonal Problems, Alienation, Persecutory Ideas, Thinking Disorder, Social Introversion, Self Depreciation), driving score, and type of driving error. In addition, a 2x4 repeated measure ANOVA was calculated to compare both cortisol levels at post-task time points 2 & 3 and 3 & 4, and to determine overall gender differences.

To determine whether there were gender differences at post-task time points 2-4, a difference score was computed by subtracting cortisol taken at each of the post-task time points from baseline. A 2x3 Groups x Time (repeated measures) ANOVA was performed.

RESULTS

Research objective #1

Correlations were calculated between state anxiety, trait anxiety, impulse expression, and salivary cortisol immediately following the driving stressor, as well as 10 - and 20 - minutes post-task (time points 2 through 4). A Pearson correlation was computed between time point one and all anxiety and impulsiveness scales as mentioned above. No significant correlations were found.

Research objective #2

As measured by the Impulse Expression subscale on the BPI, risk-taking tendencies did not vary significantly with respect to gender, $t(50) = 0.693$, not significant.

Research objective #3

Correlations for cortisol were calculated with respect to gender between state anxiety and salivary cortisol at time points 2 through 4. No significant correlations were found for either males or females. Although partial correlations were performed to control for baseline variance, no significance was found.

Exploratory Analysis

Statistical analyses of all variables with and without respect to gender were performed. As stated, there were 30 male and 25 female participants. However, 5 participants (3 male, 2 female) were excluded from the appropriate analyses due to missing data.

Means and standard deviations of each variable with respect to gender

can be seen in Tables I, II, and III. Additionally, independent sample t-tests were performed utilizing Bonferroni adjustments to determine the significant differences in all variables with respect to gender. Variables were divided into three categories: construct scores (Table I), driving score and errors (Table II), and cortisol levels in nmol/l (Table III). The Bonferroni adjustments for obtaining significance for each category were calculated to be 0.0038, 0.008, and 0.0125, respectively. Females scored significantly higher on Hypochondriasis (p=0.001) and trait Anxiety (p=0.003) than males. Males had consistently higher cortisol levels (at all time points); however, this difference was significant at baseline only p=0.008). There were no intergender differences with driving scores or errors.

Table IV contains the intercorrelations between the driving score and driving errors (see Table IV). Not surprisingly, all variables were significantly intercorrelated. Overall, braking, speeding, and acceleration errors were associated with inventory scales scores and the STAI inventory score. State anxiety, Alienation, and Deviation were significantly correlated with the participants' tendency to make braking errors (Table V). Additionally, Denial was negatively correlated with speeding errors r=-0.296, p=.037) and acceleration errors (Table VI). Moreover, Self Depreciation also shared a significant negative relationship to braking and acceleration errors (Tables V and VI, respectively).

Males

Table VII contains the intercorrelations between the driving score and driving errors for males (see Table VII). As expected, all variables were significantly intercorrelated. For males, Alienation, Persecutory Ideation, and

Deviation were all significantly associated with braking errors (Table VIII). Acceleration errors were negatively correlated with state anxiety (r=-0.386, p=0.039).

Females

Table IX contains the intercorrelations between the driving score and driving errors for females (see Table IX). As expected, all variables were again significantly intercorrelated. For females, signaling errors were positively correlated with Self Depreciation (r=0.511, p=0.013) while speeding and acceleration errors shared a negative relationship (r=-0. 465, p=0.025; r=-0.447, p=0.032, respectively). Interestingly, Self Depreciation was the only psychological measure that shared any significant relationship with driving errors for females.

Salivary Cortisol

To evaluate the HPA response to the driving task, a post hoc repeated measures ANOVA was performed to analyze differences of cortisol levels at all time points post-task. Using Greenhouse-Geisser adjustment, F(1.6, 78.03)=25.66, p<.000. Mean cortisol at each time point with respect to gender is shown in Figure 1. Further post-hoc examination comparing time points 2 & 3 and 3 & 4 yielded a significant difference for the former but not the latter.

Mean difference scores for both the overall group (Figure 2) and with respect to gender (Figure 3) were obtained by subtracting each post-task cortisol value from baseline. This was done to adjust post-task cortisol values for differences in baseline. A 2x3 Groups x Time repeated measures ANOVA was

performed using difference scores to determine gender differences present in the HPA response post-task. Males had significantly higher post-task cortisol responses than females ($F= 4.597$; $df = 1, 48$: $p<0.037$). A Box's test of homogeneity of variance was performed; the value obtained proved to be significantly different ($F= 3.230$; $df = 6$: $p<0.004$). Therefore, to determine conservatively which post-task cortisol values differed with respect to gender, independent samples t-tests with a Bonferroni adjustment (0.017) were performed for each of the three difference scores obtained. Males were found to possess significantly higher cortisol levels than females at time point 3 ($t=-2.573$, $p =0.014$ and approached significance at time points 2 ($t=-2.312$, $p=0.026$) and 4 ($t=-2.430$, $p=0.020$).

Overall or gender specific cortisol levels at all time points were not correlated with any of the inventory scores, driving score, or driving errors. The only correlation that approached significance was the driving score and cortisol at time point 2 (immediately post-task) ($r=0.239$, $p=0.077$). Controlling for salivary cortisol baseline levels (time point 1), a partial correlational matrix between post-task cortisol and inventory scores, driving score, and driving errors was performed with respect to gender. Pearson correlations were performed between cortisol and age for the overall sample. A significant positive correlation was found immediately post-task ($r=0.294$, $p=0.036$).

For males, salivary cortisol levels were not shown to correlate with any inventory score, driving score, or driving error. However, as mirrored by the entire sample, the correlation between driving score and post-task salivary cortisol

levels (time point 2) approached significance (r=0.359, p=0.071).

Analyses of females' scores, however, indicated significant partial correlations between salivary cortisol and several other variables. Self Depreciation was negatively correlated with cortisol at time points 2 and 4 and approached significance at time point 3 (p=0.09; see Table X). Persecutory Ideation correlated negatively with salivary cortisol levels at time points 3 and 4 (Table XI). For females only, cortisol shared a positive correlation with age at time point 2, 3, and 4 (Table XII).

Table I.
Statistics of Psychological Constructs.

	Mean Male	Std. Dev male	Mean female	Std. Dev Female	t score	p value
Hypochondriais	4.67	3.04	8.40	4.31	3.63	**.001**
Depression	3.89	2.86	5.52	4.59	1.55	.127
Denial	6.56	3.13	6.08	3.97	-.48	.632
Interpersonal Problems	9.89	3.92	10.84	4.16	.85	.400
Alienation	7.52	4.26	6.12	3.91	-1.23	.224
Persecutory Ideas	7.74	3.56	7.32	3.40	-.435	.665
Trait Anxiety	6.44	2.97	9.40	3.77	3.15	**.003**
Thought Disorder	4.00	3.93	4.96	3.49	-.724	.473
Impulse Expression	9.44	4.16	8.72	3.29	-.693	.492
Social Introversion	5.30	3.61	4.36	4.08	-.877	.385
Self Depreciation	3.30	3.01	3.40	4.00	.106	.916
Deviation	4.93	4.07	5.52	3.61	.556	.581
State Anxiety	33.93	10.96	38.04	11.15	1.33	.188

Table II.
Statistics of driving task variables.

	Mean Male	Std. Dev male	Mean female	Std. Dev Female	t score	p value
Driving Score	35.03	11.58	35.91	9.21	.297	.768
Signaling Errors	7.52	5.05	7.35	4.88	-.122	.903
Steering Errors	9.90	4.59	12.17	14.70	.789	.434
Braking Errors	8.93	5.46	9.00	5.10	.047	.693
Speeding Errors	8.62	8.16	9.91	8.51	.557	.580
Acceleration Errors	2.76	2.44	3.74	2.94	1.314	.195

Table III.
Statistics of mean scores salivary cortisol at time points 1-4.

Salivary cortisol Levels	Mean Male (nmol/l)	Std. Dev male	Mean female (nmol/l)	Std. Dev Female	t score	p value
Time point 1	12.44	8.25	7.52	3.59	-2.77	**.008**
Time point 2	7.35	3.28	6.32	2.66	-1.21	.232
Time point 3	6.19	2.41	5.38	1.97	-1.30	.199
Time point 4	5.84	2.31	5.06	1.84	-1.28	.206

Table IV .
Driving performance intercorrelations (overall).

Driving Performance Intercorrelations	r	p value
Driving score & Braking errors	-.415	.002
Driving score & speeding errors	.338	.014
Driving score & signaling errors	-.608	.000
Signaling errors & braking errors	.617	.000
Signaling errors & speeding errors	-.682	.000
Signaling errors & acceleration errors	-.517	.000
Braking errors & speeding errors	-.353	.010
Braking errors& acceleration errors	-.274	.050
Speeding errors & acceleration errors	.773	.000

Table V.
Braking error correlations (overall).

Braking errors	r	p value
Alienation	.300	.034
Self Depreciation	-.353	.010
Deviation	.280	.049
State anxiety	.325	.019

Table VI.
Acceleration error correlations (overall).

Acceleration errors	r	p value
Denial	-.320	.023
Self depreciation	-.288	.043

Table VII.
Driving performance intercorrelations for males.

Driving performance intercorrelations	r	p value
Signaling errors & driving score	.531	.003
Signaling errors & steering errors	-.540	.002
Signaling errors & braking errors	.545	.002
Signaling errors & acceleration errors	-.449	.015
Signaling errors & speeding errors	-.657	.000
Speeding errors & acceleration errors	.792	.000

Table VIII.
Braking error correlations for males.

Braking errors	r	p value
Alienation	.392	.043
Persecutory Ideas	.501	.008
Deviation	.410	.034

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Table IX.
Driving performance intercorrelations for females.

Driving Performance Intercorrelations	r	p value
Driving Score & Signaling Errors	-.743	.000
Driving Score & Braking Errors	-.618	.002
Driving Score & Speeding Errors	.496	.016
Driving Score & Acceleration Errors	.489	.018
Signaling Errors & Speeding Errors	-.716	.000
Signaling Errors & Braking Errors	.720	.000
Signaling Errors & Acceleration Errors	-.611	.002
Acceleration Errors & Braking Errors	-.421	.045
Acceleration Errors & Speeding Errors	.760	.000
Braking Errors & Speeding Errors	-.468	.024

Table X.
Correlations between post-task cortisol and Self Depreciation subscale.

Self depreciation	r	p value
Time Point 2	-.508	.016
Time Point 3	-.372	.088
Time Point 4	-.626	.003

Table XI.
Correlations between post-task cortisol and Persecutory Ideas subscale.

Persecutory ideas	r	p value
Time Point 3	-0.4306	0.045
Time Point 4	-0.4406	0.052

Table XII.
Correlations between age and cortisol for females

Participant age	r	p value
Time point 2	.566	.005
Time point 3	.528	.010
Time point 4	.520	.016

Fig.1. Mean cortisol at all time points for males and females.

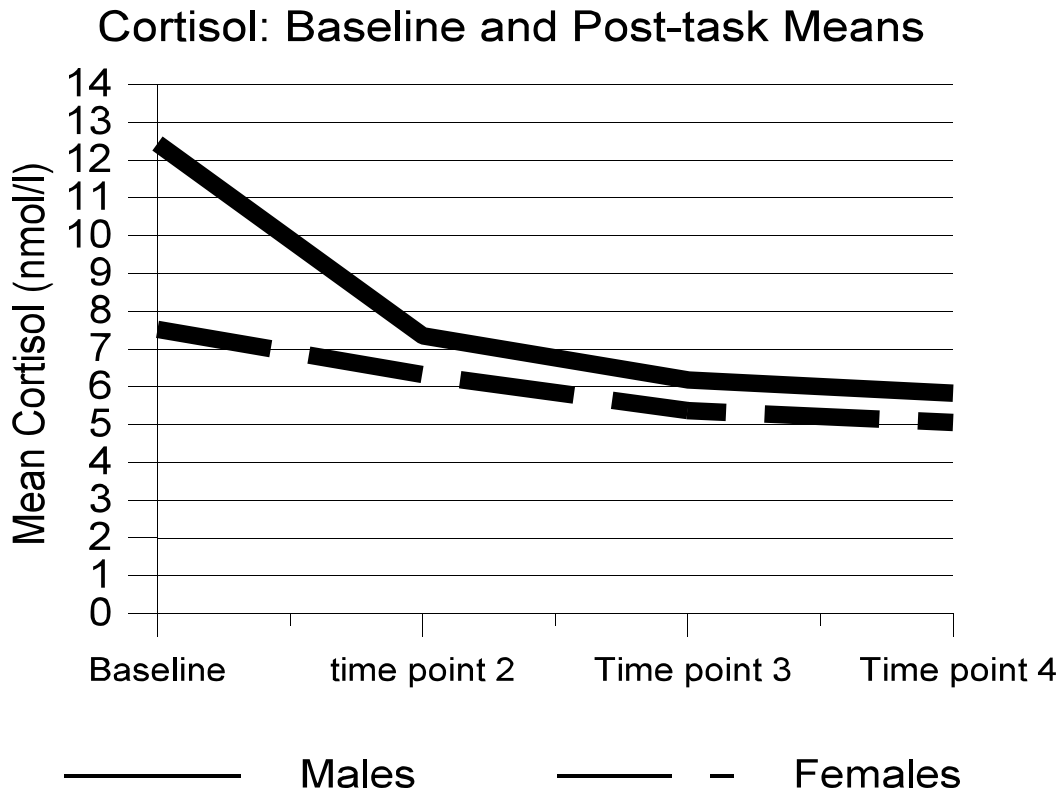


Fig. 2. Post-task cortisol responses. Means differences score for each sample taken post-task for overall group.

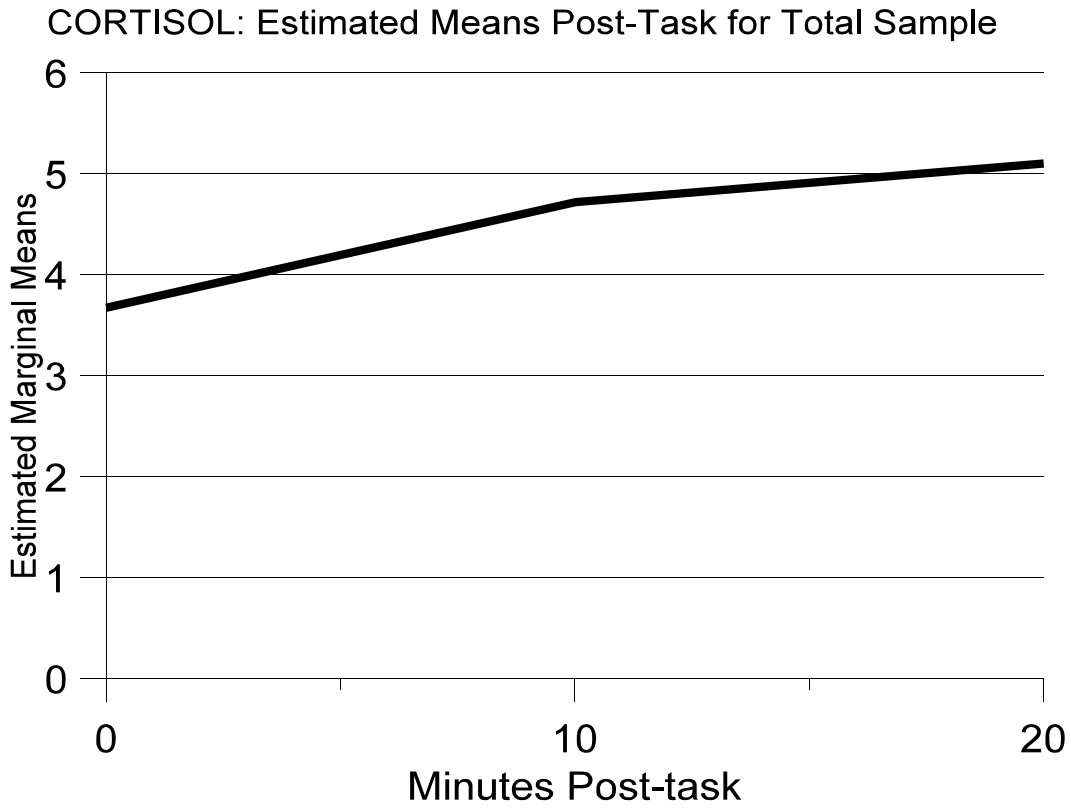
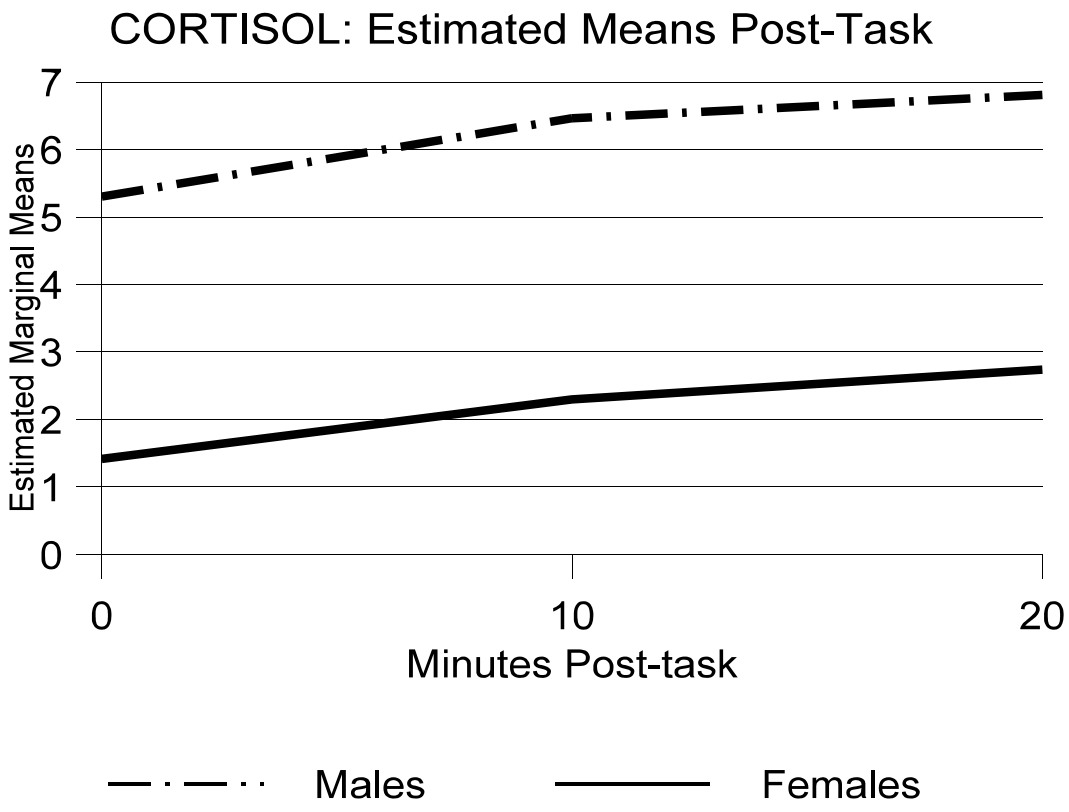


Fig. 3. Post-task cortisol responses. Means differences score for each sample taken post-task for males and females.



DISCUSSION

There were no relationships (with or without respect to gender) between salivary cortisol and both self-reported anxiety (state and trait) or impulsively measures for this sample. The driving task did, however, induce an HPA axis response (though cortisol levels remained within the normal ranges) as the means at time points 2-4 decreased systematically, indicating some physiological arousal post-task. As discussed later, slightly elevated cortisol immediately after the driving task may suggest a physiological activation and performance pattern as originally suggested by Yerkes and Dodson 1908). Unlike many studies (e.g., Aardal-Erikson et al.; 1999; Wingo et al., 1999) which demonstrate a relationship between anxiety and cortisol, this particular sample of adolescents did not provide such a correlation. The fact that no relationship between anxiety and cortisol was found was not remarkable, as contrary to expectations based on previous research (Leino et al., 1998; Sive and Hattingh, 1991; Seeman et al., 1995), participants did not appear to view the simulator task as stressful. Interestingly, when the difference scores were taken between baseline and post-task values (Figs. 2 and 3), it appears that the participants' cortisol values declined over time, but were always in normal range. Additionally, post-task state anxiety scores were in the low normal (males, 33.93) to normal ranges (females, 38.04), much lower than means reported by Speilberger (males, 54.99, females, 60.51) after a comparable naturalistic stressor -an academic exam (Speilberger, 1983). These results countered previous findings from our own laboratory, i.e., the driving task pilot study (Wingo, et al., 1999). This

discrepancy may stem from error introduced by the smaller sample size obtained from the initial findings or to other factors remaining outside the parameters of the current study.

No significant differences in impulsivity (including risk taking tendencies) or driving performance were observed with respect to gender for this sample. These results were also unexpected, as other findings demonstrated significant gender differences with respect to motor vehicle accident rates (Massie et al., 1997; Insurance Institute for Highway Safety, 1997) and impulsivity (Krishna, 1981). Additionally, the lack of a relationship between impulsivity and driving performance with this sample was unexpected, for Vavrik had reported that high-risk adolescent drivers had much higher risk-taking tendencies than lower-risk drivers (Vavrik, 1997).

Although no gender differences were found between state anxiety and impulsivity measures, trait anxiety was significantly higher for females than males. As cited by Jackson (1996), an unpublished study by Smiley and Jaffe found similar gender differences in the BPI Anxiety subscale with normal adolescents. Additionally, this measure had no association with cortisol levels anytime point. Males were shown to have a higher overall cortisol baseline and overall post-task responses than females in this study. Specific elevations were seen (with a Bonferroni adjustment at 0.017) at time point 3 ($p=0.014$) with time points 2 ($p=0.026$) and 4 (0.020) approaching significance. Brandstadter et al. (1991) reported that adult males ages 35-65 had greater afternoon unstimulated

cortisol levels than females. Although the males in the current study are adolescent, the combined results may suggest that basal cortisol levels (and thus deviations from) may be independent of the anxiety or risk taking constructs used in this study.

Salivary cortisol levels were not correlated (with or without respect to gender) to any of constructs or driving performance scores in this study. As a result, partial correlations were performed with respect to gender in part to account for variance introduced by the elevated baseline. With partial adjustments, significant correlations between post-task cortisol and several BPI constructs reached significance. Furthermore, unusual patterns were revealed when correlational matrices examined between BPI constructs and driving errors. For females only (controlling for baseline) cortisol levels at time points 2 and 4 (with time point three approaching significance, $p=0.09$) were inversely correlated with Self Depreciation scores. Additionally, females had Persecutory Ideas scores which also demonstrated negative relationships to cortisol levels at time points 3 and 4.

Although males shared no significant relationships between cortisol and inventory scores, the correlation between post-task cortisol and driving performance approached significance ($p=0.07$). This also held true for the entire sample ($p=0.08$). The correlation was positive, suggesting that some HPA activation may be facilitative for successful driving task performance. This is not a novel idea, as Yerkes and Dodson first proposed such a curvilinear relationship

between performance and anxiety (Yerkes and Dodson, 1908) and indeed other literature supports this concept (e.g., Kelly et al., 1998).

For the entire sample, examination of individual scores and driving abilities indicated that Denial was inversely associated with speeding and acceleration errors while braking errors were positively correlated with Alienation, Deviation, and state anxiety. Jackson (1996) suggests that high scorers on Denial tend to be defensive and deal with stress through "active flight or avoidance." The data suggests that errors which involve active participation in speed control (and thus requiring a more active role to the task) are inversely associated with this type of avoidance. On the other hand, Jackson (1996) summarizes that a high score on Alienation and Deviation may indicate attitudes and behavior patterns which depart from social norms. As a result, voluntary control of vehicular braking may be a function of not only the neural mechanisms which mediate the current level of anxiety, but also those that regulate the attitudes and behavior that facilitate social integration with the rest of society.

For males, state anxiety was negatively correlated with acceleration errors and Alienation was positively associated with braking errors. In addition, braking errors were also associated with the tendency to have higher Persecutory Ideas scores. Jackson (1996) defines a high score on Persecutory Ideas as a tendency to see others as hostile who make "life difficult and unpleasant." These results may imply a link between the voluntary motor control of the stopping and starting of a vehicle and neural regulation of socially inappropriate attitudes and behaviors. Furthermore, coupled with a sense of

environmental uncertainty, as described by Goldstein (1995) and Kelly et al (1998), elevated state anxiety may actually serve as a catalyst for making fewer acceleration mistakes.

For females, the only subscale which correlated with driving errors was Self Depreciation: positively with signaling errors and negatively with speed and acceleration errors. Interestingly, as stated previously, Self-Depreciation correlated significantly with cortisol at post-task (time point 2), 20 minutes post-task (time point 4) and nearly significant at 10 minutes post-task (time point 3). Thus, it can be posited that the greater the self depreciating tendencies a female in this sample had, the lower the cortisol levels were at all post task time points. Furthermore, this group also had the fewest errors with motor control of vehicular speed and acceleration. Because this particular subscale is associated with poor self image and low self esteem, this very usual pattern must be examined more closely (Jackson, 1996).

Zorilla and coworkers (1995) found that high self esteem was associated with high circulating plasma cortisol levels at rest in young men (18-19 years old). They attributed this seemingly counterintuitive link to reduced stress responsiveness due to higher basal cortisol levels. That is, higher basal cortisol levels may serve to protect the organism from mood disruption of a stressor induced cortisol increase. With this in mind, the lack of association of cortisol to any of the pen and paper constructs for males (as well as higher basal levels) may be explained as a lack of stress responsiveness to the usual mood disrupting effects of stress. This also may account for the inverse relationship

with the post task cortisol levels and Self Depreciation scores in females, for it was found within this sample that higher self esteem was associated with greater activation of the HPA axis. This suggests a possible gender specific physiological mechanism protecting elements of mood contributing to higher self esteem.

In another study teachers with low self esteem, higher burnout, and higher perceived stress had lower overall cortisol secretion (Pruessner et al., 1999(a)). It was suggested that perhaps this lack of HPA activation to stress was indeed a dysregulation due to exhaustion to fatigue. This, in turn, suggests that the lack of HPA activation is due to the organism entering the exhaustive phase, as described earlier by Selye (Selye, 1976).

Finally, a study conducted by Pruessner and others examined the relationship between cortisol levels and self esteem after induced success and failure mental arithmetic tests (Pruessner et al., 1999(b)). Though self esteem was negatively correlated with cortisol in the failure condition, it was not in the successful condition, suggesting that self-esteem is much like a “buffering” agent when it comes to preventing a stress response in a hopeless situation.

Perhaps, as discussed earlier, a certain amount of elevation in glucocorticoid release during a novel task is beneficial to the organism. For both sexes, there was a significant decline at each time point after the driving task, indicating that indeed some amount of physiological arousal had occurred. Males, who demonstrated the lack of a relationship between cortisol and any personality or mood construct given, have elevated baseline cortisol release and

a significantly lower trait anxiety than females. This may indicate a possible protective mechanism facilitated by an elevated HPA tone.

Adolescent females, who it must be remembered have a much lower vehicular collision and fatality rate, demonstrated improved performance after the driving task (with respect to driving errors) if they maintained a lower HPA axis response when elevated trait tendencies of self depreciation (low self esteem) and persecutory ideation were present. Perhaps this subset of females maintains a cognitively adaptive advantage over other females in that they display greater voluntary motor task vigilance, conceivably with a proverbial “axe to grind” because of a certain belief that they, as well as others, think poorly of themselves. More specifically, a dimorphic neural link may exist between the limbic, temporal and frontal systems (both dorsal and ventral) which regulate critical social and self perceptions and certain aspects of visual-spatial/motor learning.

Another interesting gender specific relationship found was that between age and cortisol. The correlation was positive and significant for females at all post-task time points and only immediately post-task for the entire group. While these findings are appealing, there is remarkably little consensus regarding relationships between age and cortisol release. Brandtstadter et al. found that unstimulated morning cortisol was inversely correlated to age for adult females (1991) while a positive correlation was found irrespective of gender and time of day between cortisol and pubertal stage (Keiss et al., 1995). Furthermore, it has been suggested by Wittling and Pfluger (1990) that some aspects of cortisol

release may be modulated (perhaps even increased) by the right hemisphere, particularly by the subcortical regions. It is possible that as an adolescent female approaches adulthood, development of neuroendocrine regulation may be taking place in the right hemisphere which would mediate a *greater* cortisol response to a demanding task.

There is undeniably more gender specific adolescent stress research that must be done to delineate and clarify the reasons for discrepancies in physiological stress response and real world driving performance. When these conundrums are made less nebulous, much insight may be gained into the intrinsic physiological and psychological differences between the sexes, whether it is in childhood, adolescence, or adulthood.

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